TOUGHENED THERMAL BLANKET FOR MMOD PROTECTION

Eric L. Christiansen[1] and Dana M. Lear[2]

[1]NASA Johnson Space Center, Mail Code KX, 2101 NASA Parkway, Houston, TX 77058, Eric.L.Christiansen@nasa.gov
[2]NASA Johnson Space Center, Mail Code KX, 2101 NASA Parkway, Houston, TX 77058, Dana.M.Lear@nasa.gov

ABSTRACT

Thermal blankets are used extensively on spacecraft to provide passive thermal control of spacecraft hardware from thermal extremes encountered in space. Toughened thermal blankets have been developed that greatly improve protection from hypervelocity micrometeoroid and orbital debris (MMOD) impacts. These blankets can be outfitted if so desired with a reliable means to determine the location, depth and extent of MMOD impact damage by incorporating an impact sensitive piezoelectric film.

Improved MMOD protection of thermal blankets was obtained by adding selective materials at various locations within the thermal blanket. As given in Figure 1, three types of materials were added to the thermal blanket to enhance its MMOD performance: (1) disrupter layers, near the outside of the blanket to improve breakup of the projectile, (2) standoff layers, in the middle of the blanket to provide an area or gap that the broken-up projectile can expand, and (3) stopper layers, near the back of the blanket where the projectile debris is captured and stopped. The best suited materials for these different layers vary. Density and thickness is important for the disrupter layer (higher densities generally result in better projectile breakup), whereas a high-strength to weight ratio is useful for the stopper layer, to improve the slowing and capture of debris particles. The spacer layer should provide volume with minimum mass. Several toughened

thermal blanket configurations incorporating a variety of materials (see Table 1) were evaluated in this study by means of hypervelocity impact tests at the NASA White Sands Test Facility (WSTF) and at the University of Dayton Research Insititute (UDRI). From these tests the best disrupter materials were found to be beta-cloth and fiberglass fabric. Polyimide open-cell foams provide a light-weight means to increase the blanket thickness and improve MMOD protection. Lightening holes can be punched through the foam to decrease the mass of the spacer even more. The best stopper material is Spectra 1000-952. An Al 2024-T3 plate was used as the spacecraft surface or rear wall. Two failure modes were considered: (1) a complete penetration of the thermal blanket, and (2) perforation of the spacecraft surface or rear wall. A standard thermal blanket used as comparison in this testing has a mass per unit area of 0.065 g/cm^2, and is easily penetrated by a 0.4mm diameter aluminum spherical projectile at 7.1 km/s. In contrast, a toughened thermal blanket with two (2) layers of fiberglass FG-7781 cloth, 1” (2.5cm) thick open-cell polyimide foam and three (3) layers of Spectra 1000-952 stops a 1.3mm diameter aluminum spherical projectile at 7.1 km/s. This blanket has a mass per unit area of 0.212 g/cm^2. A toughened blanket with 6” of open-cell polyimide foam, 12 layers of FG-7781 and 12 layers of Spectra 1000-952 (0.805 g/cm^2 overall) is able to stop a 6.0 mm diameter aluminum projectile at 6.9 km/s. This factor of 10 increase in particle size stopped translates into a factor of 1000 decrease in MMOD penetration risk.

Ballistic limit equations were derived from the work for use in sizing toughened thermal blankets for spacecraft applications and for use in MMOD risk assessments for NASA spacecraft. Figure 2 illustrates the predicted ballistic limits using these equations compared to test data for one of the toughened thermal blanket configurations tested (type 3 configuration).

A thin-film flexible impact sensor has been integrated into thermal blankets to detect and locate MMOD impact damage. The sensor provides data on the location and extent of MMOD impact damage to the thermal blankets which can be used to monitor the integrity of thermal protection. The impact sensors are monitored by electronics and sensor output is displayed to show the location, extent and time of impact damage. The approach is to use piezoelectric thin-film sensor technology. The sensor panels are low mass (0.13 kg/m^2), highly flexible, divided into multiple pixels (48 to 96 pixels in typical applications) and internal connections made by flexible printed circuitry. Each pixel is electrically connected to a set of panel electronics which collects the electrical signals and determines where the impact occurred and the extent of the damage. The panel electronics then communicates this information to the central electronics where the data is recorded or relayed to space or ground displays.

Figure 1. MMOD Toughened Thermal Blanket Configuration.

Table 1. Materials Evaluated for Toughened Thermal Blanket.		
Element	**Material Candidates**	**Mass / Area (g/cm^2)**
Disrupter Layer	Beta Cloth Fiberglass Cloth Nextel	5mil beta cloth: 0.025 g/cm^2 FG 7781: 0.029 g/cm^2 Nextel AF10: 0.0292 g/cm^2
Spacing Layer	Open Cell Foam (polyimide foam) Polymer Batting	Polyimide AC 550 foam 1.0” thick: 0.018 g/cm^2 AC 530 foam, 1” thick: 0.014 g/cm^2 Polyester 1.0” thick foam: 0.081 g/cm^2
Stopper Layer	Spectra (Polyethylene) Kevlar (Aramid) Beta Cloth	Spectra 1000 style 955 – 0.0112 g/cm^2 Spectra 1000 style 952 – 0.0237 g/cm^2 Kevlar KM2 style 705 – 0.0244 g/cm^2 Kevlar 159 style 779 – 0.0132 g/cm^2 5mil Beta Cloth – 0.025 g/cm^2

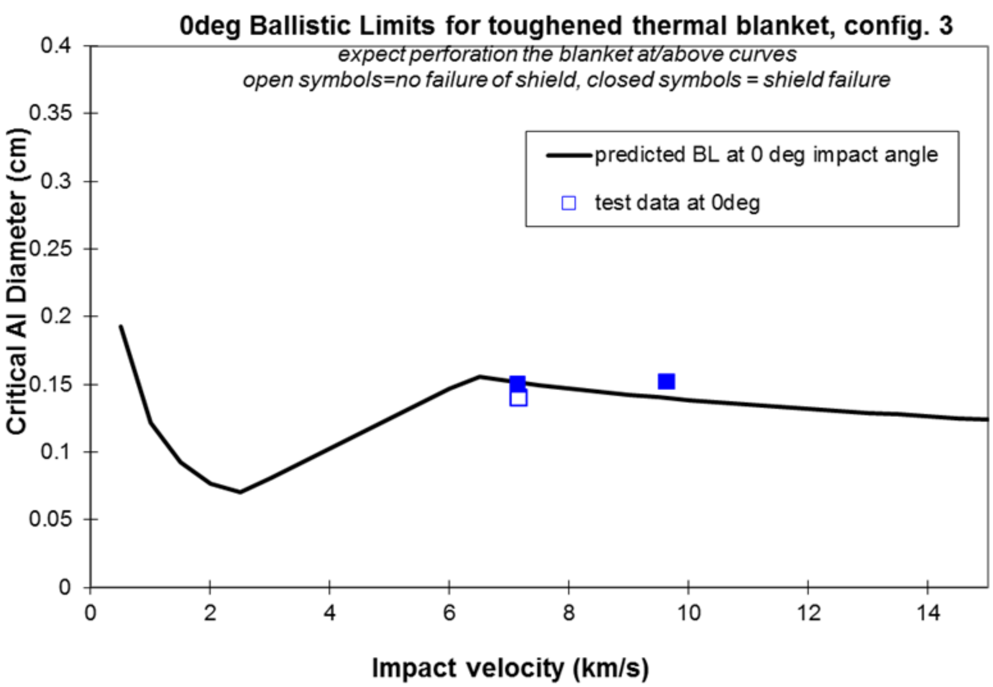

Figure 2. Ballistic limit predictions and impact test data for 0 deg impacts by aluminum projectiles on toughened thermal blanket configuration 3.